

CLAIMS

What is claimed is:

- 1 1. A method of substantially removing jitter from a stream of packets transmitted
2 from a transmission site to a reception site, the method comprising the steps of:
3 buffering packets of the stream of packets in a memory at an intermediate site
4 interposing the transmission site and the reception site, wherein selected
5 packets of the stream of packets include timestamps having time values for
6 an external clock;
7 locking a first local clock with the time values of the timestamps included in the
8 selected packets to the external clock; and
9 extracting packets from the memory at a nominal rate controlled by a second local
10 clock, wherein the second local clock is locked with the time values of the timestamps of
11 the selected packets extracted from the buffer based on the first local clock.

- 1 2. The method of claim 1, prior to the step of buffering, further including the steps
2 of:
3 receiving from the transmission site at the intermediate site the stream of frames,
4 wherein each frame encapsulates at least one packet therein;
5 de-encapsulating the at least one packet from each frame of the stream of frames;
6 and
7 providing the packets to the memory.

- 1 3. The method of claim 2, prior to the step of locking, further including the step of:
2 calculating an average bit rate for the received stream of frames between a first
3 timestamp and a second timestamp;
4 calculating an offset for the second timestamp using the average bit rate; and
5 subtracting the offset from the time value of the second timestamp.

- 1 4. The method of claim 3, wherein the step of calculating the average bit rate further
2 includes the steps of:
- 3 receiving a first particular frame of the stream of frames, the first particular frame
4 having a first particular selected packet having the first timestamp therein;
5 receiving a second particular frame of the stream of frames, the second particular
6 frame having a second particular selected packet having the second
7 timestamp therein;
8 determining the number of bits of packets between the first timestamp and the
9 second timestamp inclusive of either the first timestamp or the second
10 timestamp; and
11 dividing the number of bits by the time difference between the first timestamp and
12 the second timestamp.
- 1 5. The method of claim 3, wherein the step of calculating the offset further includes
2 the steps of:
- 3 receiving a particular frame of the stream of frames having multiple sequential
4 packets including a particular selected packet having the second timestamp
5 therein;
6 determining the number of bits of packets between the particular packet and the
7 start of the sequence of the multiple packets; and
8 dividing the number of bits by the average bit rate.
- 1 6. The method of claim 1, further including the step of:
2 recording a time measured relative to the second clock, wherein the recorded time
3 is associated with when one of the selected packets is extracted from the
4 memory.

- 1 7. The method of claim 6, further including the step of:
2 stamping a new time in the timestamp of the selected packets, wherein for each
3 selected packet the new time compensates for variable delay between
4 when the packet is transmitted from the intermediate site and when the
5 packet was extracted from the memory; and
6 transmitting from the intermediate site packets extracted from the memory,
7 wherein the time values of the timestamps in the selected packets are
8 transmitted substantially jitter free.
- 1 8. The method of claim 1, further including the step of:
2 stamping a new time in the timestamp of the selected packets extracted from the
3 memory using the second local clock to set the time.
- 1 9. The method of claim 1, further including the steps of:
2 recording an extraction time for each selected packet extracted from the buffer,
3 wherein the extraction time for each selected packet corresponds to the
4 time of the second local clock when the selected packet was extracted from
5 the memory;
6 associating each extracted selected packet with its extraction time;
7 determining a variable delay time for each extracted selected packet using the
8 extraction time for the extracted selected packet, wherein the variable
9 delay time corresponds to the delay between extraction from the memory
10 and transmission from the intermediate site of the packet;
11 determining a new time value for the timestamp of each selected packet using the
12 variable delay time and the second local clock.

1 10. A method of substantially removing jitter from a stream of packets transmitted
2 from a transmission site to a reception site, the method comprising the steps of:
3 receiving at an intermediate site a stream of frames, each frame encapsulating a
4 set of packets, wherein selected packets include a timestamp defining a
5 time value for a clock external to the intermediate site;
6 de-encapsulating the set of packets from each frame;
7 determining whether the set of packets from each frame includes a given selected
8 packet having a timestamp therein;
9 responsive to the set of packets including the given selected packet, determining a
10 time offset for the given selected packet, wherein the time offset is based
11 upon the position of the given selected packet within the frame in which
12 the given selected packet was received, and stamping a new time value in
13 the timestamp of the given selected packet, wherein the new time value is
14 defined by subtracting the time offset from the time value for the external
15 clock; and
16 transmitting the packets from the intermediate site at a predetermined rate.

1 11. The method of claim 10, wherein the step of determining a time offset further
2 includes the steps of:
3 calculating for the stream of frames an average bit rate, wherein the average bit
4 rate is defined as the number of bits of packets between a first timestamp
5 included in a first selected packet and a second timestamp included in a
6 second selected packet inclusive of either the number of bits in the first of
7 the second timestamp divided by the change in time between the time
8 values of the first and second timestamps;
9 determining for the set of packets that includes the given selected packet the
10 number of packet bits between the start of the set of packets and the first
11 bit in the given selected packet; and
12 dividing the number of packet bits by the average bit rate to generate the time
13 offset.

1 12. The method of claim 10, further including the steps of:
2 recording a first local clock time for each selected packet, the first local clock time
3 corresponding to when the frame carrying the selected packet arrived at
4 the intermediate site;
5 buffering in a memory the packets carried by the stream of frames;
6 extracting packets from the memory at a rate clocked by the local clock; and
7 prior to transmitting each selected packet, recording a second local clock time and
8 generating calculating for the stream of frames an average bit rate, wherein the
9 average bit rate is defined as the number of bits of packets between a first
10 timestamp included in a first selected packet and a second timestamp
11 included in a second selected packet inclusive of either the number of bits
12 in the first of the second timestamp divided by the change in time between
13 the time values of the first and second timestamps;
14 determining for the set of packets that includes the given selected packet the
15 number of packet bits between the start of the set of packets and the first
16 bit in the given selected packet; and
17 dividing the number of packets bits by the average bit rate to generate a
18 transmission time.

1 13. An apparatus for substantially removing jitter from a stream of packets
2 transmitted from a transmission site to a reception site, the apparatus located at an
3 intermediate site and comprising:
4 a buffer having packets of the stream stored therein, wherein selected packets of
5 the stream of packets include a timestamp, each timestamp having a time
6 value from a clock external to the apparatus stamped therein;
7 a buffer controller adapted to extract time values from the selected packets and
8 extract packets from the buffer;
9 a first locked loop having a first local clock, the first locked loop receiving time
10 values from the buffer controller and locking the first clock thereto;
11 a second locked loop having a second local clock, the second locked loop
12 receiving timing information relative to the first local clock and locking
13 the second local clock thereto, wherein the buffer controller receives
14 timing signals from the second local clock and extracts buffered packets at
15 a rate measured relative to the second local clock.

- 1 14. The apparatus of claim 13, further including:
2 a transmitter adapted to receive packets extracted from the buffer and transmit the
3 packets therefrom, wherein the time value for each selected packet
4 extracted from the buffer is set relative to the second local clock.
- 1 15. The apparatus of claim 13, wherein responsive to the buffer receiving a given
2 selected packet, the buffer controller provides the first locked loop with the time value of
3 the given selected packet.
- 1 16. The apparatus of claim 13, wherein responsive to the buffer controller extracting a
2 given selected packet from the buffer, the buffer controller provides the second locked
3 loop with the time value of the given selected packet.
- 1 17. The apparatus of claim 13, further including:
2 means for receiving a stream of frames, each frame of the stream of frames
3 encapsulating a set of packets of the stream of packets arranged in a given
4 order; and
5 an unencapsulator adapted to unencapsulate the set of packets from each frame of
6 the stream of frames and to provide the packets of each set to the buffer in
7 the given order.
- 1 18. The apparatus of claim 17, wherein the unencapsulator is further adapted to
2 determine a temporal offset for a given selected packet included in a given set of packets
3 by the location of the given selected packet in the given set of packets.
- 1 19. The apparatus of claim 18, wherein the unencapsulator is further adapted to
2 determine a new time value by subtracting the temporal offset from the time value of the
3 timestamp of the given selected packet and stamp the new time value in the timestamp of
4 the given selected packet.
- 1 20. The apparatus of claim 13, wherein the timing information received by the second
2 locked loop is the current time of the first local clock minus an offset.

1 21. The apparatus of claim 20, wherein the offset is a predetermined time
2 corresponding to desired length of time that a given packet resides in the buffer.

1 22. An apparatus for substantially removing jitter from a stream of transport packets
2 transmitted from a transmission site to a reception site, the apparatus located at an
3 intermediate site and comprising:

4 an input port adapted to receive a stream of network frames carrying the stream of
5 transport packets;

6 a de-encapsulator in communication with the input port adapted to extract the
7 transport packets from the network frames;

8 a buffer in communication with the de-encapsulator having transport packets of
9 the stream of transport packets stored therein, wherein selected transport
10 packets include a timestamp, each timestamp having a time value from a
11 clock external to the apparatus stamped therein;

12 a first locked loop having a first local clock, wherein the first locked loop receives
13 a time value related to the timestamp of the last buffered selected packet
14 for locking the first local clock thereto;

15 a buffer controller in communication with the buffer and the first locked loop, the
16 buffer controller adapted to provide the time value related to the timestamp
17 of the last buffered selected packet to the first locked loop and extract
18 packets from the buffer at a predetermined rate on a first-in first-out basis,
19 and wherein the rate of extraction is such that the extracted packets are
20 substantially jitter free; and

21 a second locked loop in communication with the buffer controller and the first
22 locked loop, the second locked loop having a second local clock, the
23 second locked loop receiving timing information relative to the first local
24 clock and locking the second local clock thereto, wherein the buffer
25 controller receives timing signals from the second local clock and the rate
26 of extraction is measured relative to the second local clock.

1 23. The apparatus of claim 22, further including:

2 a transmitter adapted to receive packets extracted from the buffer and transmit the
3 packets therefrom, wherein the time value for each selected packet
4 extracted from the buffer is set relative to the second local clock.

1 24. The apparatus of claim 22, wherein responsive to the buffer receiving a given
2 selected packet, the buffer controller provides the first locked loop with the time value of
3 the given selected packet.

1 25. The apparatus of claim 22, wherein the buffer controller provides feedback to the
2 second locked loop.

1 26. The apparatus of claim 25, wherein responsive to the current first-in transport
2 packet being one of the selected transport packets, the feedback provided by the buffer
3 controller is related to the time value of current first-in transport packet.